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ALASKA FOREST RESEARCH

PROBLEMS AND PRESENT STATUS

STATION PAPER NO. 4

ANNUAL REPORT - 1955

ALASKA FOREST RESEARCH CENTER
U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
JUNEAU, ALASKA
R. F. TAYLOR, FORESTER IN CHARGE

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1955 ANNUAL REPORT

ALASKA FOREST RESEARCH CENTER

The continued movement of industry northward in British Columbia and along the coast into Alaska makes it evident that the long unused forest resources of Southeast Alaska will soon be in full use. There is a need to take stock of the present status of things and to make more definite plans for developing the resources, not only in Southeast Alaska, but in the Interior and along the coast to "the westward".

Since the establishment of the Alaska Forest Research Center in 1948, pulp mills and related industry have spoken for all four management units of the Tongass National Forest. The Ketchikan Pulp Company has begun operations in the Ketchikan unit and timber sales have been awarded to the Pacific Northern Timber Company in the Petersburg-Wrangell unit, to the Georgia-Pacific Company for the Juneau unit, and to the Alaska Lumber and Pulp Company, Ltd. of Tokyo for the Sitka unit.

The Alaska Forest Research Center is the only forest research organization in Alaska. It began its work just as the first of these four large companies came into the picture. It begins to be obvious that forest research cannot keep pace with the problems of pulp timber cutting already well under way. Research should have had more of a head start. This is not a new observation; it has been a problem in most forest regions. Research arrives, in many cases, just as industry is taking a breather to look for more timber to cut in some new region. Will that be a warning so that forest research will know the problems in the Interior and have the important ones solved before industry begins active utilization of the timber resource? There has been no forest research in the Interior or in the coastal forests to the westward except for a 4-summer study (1949-1952) by the Research Center to determine the effect of fire on Interior vegetation, including timber. Since 1952 the Center has had to husband all of its finances for the urgent work in Southeast Alaska.

AN IMPORTANT FOREST RESOURCE

The interior of Alaska has in the neighborhood of 180 billion board feet on about 40 million acres of commercial forest land, or about three times as much volume as the New England states. Southeast Alaska has about 70 billion feet or as much as the middle Atlantic states. These are not "stunted arctic stands" (fig. 1). Merchantable-sized trees are found well north of the Arctic Circle. To get an accurate picture of the resource a forest inventory must be made. This is being done in Southeast Alaska where more accurate figures are urgently needed to replace the data obtained in rough cruises. The figures for the Interior are based only on estimates by experienced foresters engaged in fire protection. Even if an accurate forest inventory of the Interior eventually shows somewhat less than these estimates, there is still a great forest resource.

Forest Research Involved

To manage a forest resource it is necessary to know as a minimum (a) the location and volume of merchantable stands and location of land capable of growing merchantable stands, (b) the rate of present and potential growth, (c) how to harvest the timber crop to provide for reproduction of the best kind, (d) how to treat new crops to promote quantity and quality growth, and (e) how to protect all forest land from fire, insects and disease.

Management assumes utilization. Forests cannot be managed under sustained yield without removing crops of timber. In Southeast Alaska utilization for pulp and lumber is under way. In the Interior utilization is yet to come. To assist in developing forest industry in the Interior products utilization research and service is needed.

The work needed under these broad headings may be outlined as follows:

Forest Inventory

a. Areas and volumes
b. Growth and mortality, present stands.

Protection

a. Fire studies to aid in detection and suppression - Interior
b. Insect research and surveys
c. Disease research and surveys
    Visible indicators of cull and defect

Forest Management Research

a. Harvesting methods by forest type and condition

    1. Clear cutting or partial cutting
    2. Methods of reproducing stands

        (a) Basic studies of silvics of species and site factors
        (b) Treatment of cutover areas

b. Stand improvement

    1. Treatment of young stands
    2. Treatment of unmerchantable stands

c. Working tool studies

    1. Volume tables
    2. Growth and yield tables

d. Related studies

    1. Effect of logging on watersheds

        (a) Effect on streams and fish
        (b) Effect on wildlife
        (c) Erosion and water yield effects

Forest Products Utilization Research and Service

a. Best use of species and grades
b. Service in establishing industries

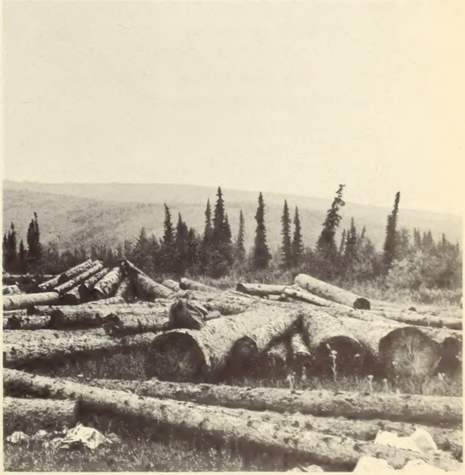


Figure 1.—Interior logs are of good size.

Fires burn an average of a million acres each year in the Interior of Alaska. Bureau of Land Management foresters are gradually decreasing this loss but fire research is needed to help their efforts. A selling job is in order in the Interior to convince Alaskans that there is a resource worth protecting and that fire will not improve the present stands. The average citizen does not realize that much of the best timber is not visible from highways or railroads, as fire has burned and reburned these belts.

Insects and disease cause at least as much loss of timber as fires, but less can be done about it. A forest entomologist at the Research Center makes yearly surveys to locate possible epidemics of forest insects in the Interior as well as in Southeast Alaska. He determines the extent of damage and whether control measures are practical. He studies these insects as best he can on funds available.

Several short trips have been made over the Interior by stateside forest pathologists to get a general idea of diseases present. More detailed surveys and some studies have been made in Southeast Alaska so that at present we have some rough guides for defect allowances on forest inventory work. At present no forest pathology research or surveys are being conducted. With full utilization of some 70 billion feet of timber on the Tongass National Forest approaching, the services of a forest pathologist will be urgently needed.

Forest management studies have been under way in Southeast Alaska since 1948, although on a modest scale considering the value of the resource and the planned investment in pulp mills. Results of research from similar forest types in the states could not be applied. Too many conditions were just different enough to call for a great deal of checking and much entirely new research. It is predicted that the Interior will also be too unique for application of research results elsewhere. To be sure, the white birch and white spruce of the Interior also occur in Canada, the Lake States, and further east, but here we have 20-hour days during the growing season and permafrost over much of the area. The probability of winter logging which does not disturb the seed bed makes regeneration difficult.

The study of the effect of fire on vegetation, now being published as a government bulletin, gave some indications of growth rates in the Interior which are as good, in general, as growth rates in similar forest types in southern Ontario and northern Maine. However, there are no adequate volume tables for cruising, or growth and yield tables to determine potential growth and length of rotation. It is quite probable that growth rates could be much improved if we knew more about the effects of the important site factors.

One of the principal reasons for the slowness in development of wood-using industries in the Interior has been lack of information which a forest inventory would furnish. Another is that information concerning the possible uses of the species for various products and the possibilities of getting the proper grades and types of wood for them has been lacking. A forest utilization service unit such as those attached to various stateside forest experiment stations would be of great help in furthering industrial use of the Interior stands. It would also be of assistance in creating new small industries in Southeast Alaska.

In our 1954 annual report, the first issued for general distribution, brief explanations of past work were included. This report carries on from there to give results of research during 1955.

THE FOREST SURVEY

The forest inventory of Southeast Alaska is a cooperative project between the Alaska Forest Research Center and Region 10 of the U. S. Forest Service at Juneau, Alaska. Practically all of the commercial forest land of Southeast Alaska is in the Tongass National Forest. Initiated in 1954, this inventory will be the first comprehensive source of facts on the condition and use of the timber resource of this area. The construction of Alaska's first pulp mill at Ketchikan in 1954 and the increasing interest of additional pulp companies and other wood-using firms have made it imperative that the administrators of the 16 million-acre Tongass National Forest obtain accurate data on which to base management of this vital resource. Forest statistics are being obtained for the various timber management working circles of this forest.

Three field parties of two men each measured sample plots and obtained data on about 1,700,000 acres of forest land - of which 95 percent was accessible only by boats and float planes. Roads and trails are practically non-existent in this vast virgin wilderness. Field work was completed for the Juneau timber management working circle unit. A start was also made on both the compilation of data and the cover type map for this unit. In addition, about two-thirds of the photo-interpretation job of the Petersburg timber management working circle unit was completed.

A preliminary plan for a study of timber utilization and drain for Southeast Alaska was prepared.

Since there was no cottonwood board foot volume table for Southeast Alaska, a study was made to test the possible adaptation of the Girard Form-Class volume tables for 16-foot logs. Tree measurement data were taken on a sample of cottonwood trees and the resultant test showed that the Girard tables are well suited to cottonwood. The tables showed an aggregate deviation of less than seven-tenths of one percent and an average deviation of nine percent.

Figure 2.--Forest Survey field parties have completed inventory of field plots in an area involving over 1,350,000 acres of productive forest land. (See map, fig. 3.)

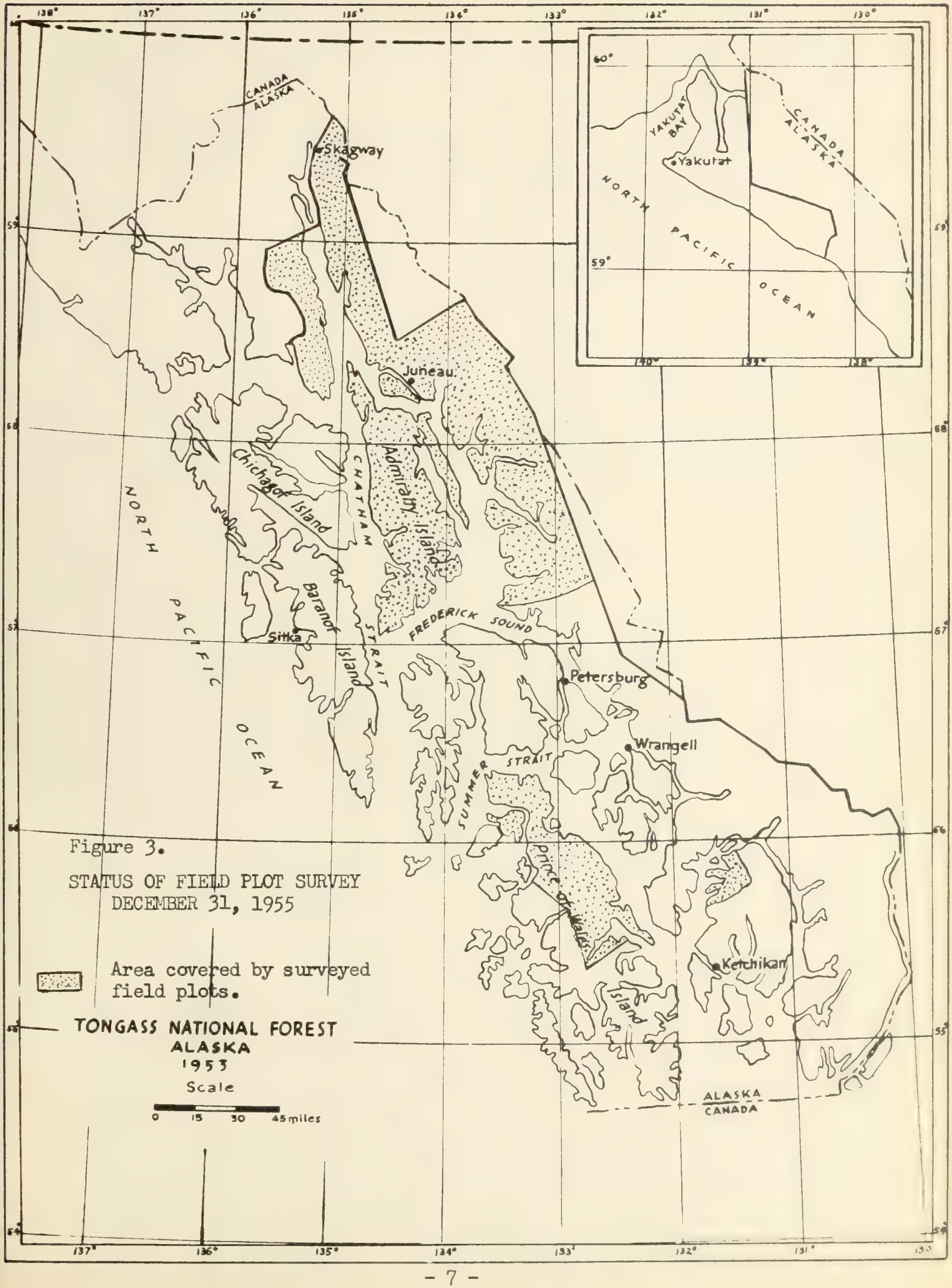


Figure 3.

STATUS OF FIELD PLOT SURVEY
DECEMBER 31, 1955

Table 1.--Status of the forest survey, December 31, 1955

Area	Forest area	Proportion of job done			
	M acres	Total job	Field inventory	Type maps	Reports
Southeast Alaska	11,517	15%	24%	10%	6%

Plans for 1956

1. Publish report on the forest resource of the Juneau timber management unit.

2. Prepare a type map, at 2 inches to the mile, for the Juneau unit insofar as base maps are available.

3. Complete field plot survey of the Petersburg unit.

4. Commence both compilation of data and typemapping of the Petersburg unit.

5. Complete a part of field plot survey of the Sitka unit.

FOREST INSECTS

The Black-Headed Budworm Survey

The black-headed budworm outbreak has been systematically followed by annual fall surveys since 1952. As in previous years forest rangers and other field personnel were relied upon to collect hemlock twigs from which the budworm egg counts were made.

An unusually wet, cold summer retarded budworm development throughout the entire life cycle and this retardation caused such a delay in the egg sampling that some areas had to be passed up as rough weather set in.

Present status

The heart of the black-headed budworm outbreak during 1955 was in Excursion Inlet. In this relatively small area on the north side of Icy Strait budworm defoliation was very heavy and top killing is most likely to occur. Defoliation extended from the shore to timberline and was heaviest at the lower elevations up to approximately 1000 feet. The hemlock sawfly was also abundant in this area. On September 21 when examinations were made for budworm eggs, the budworm was mostly in the pupal stage and no eggs were found. Night temperatures were below freezing at that time.

Areas of lighter budworm defoliation extended west of Excursion Inlet to the west side of Glacier Bay and south along the northwest portion of Chichagof Island. Many of the latter areas were heavily defoliated in 1954 and top kill of hemlock is common.

Very noticeable budworm defoliation occurred on mountain and western hemlock in the Endicott River area and on spruce near the headwaters of the Skagway River. Both areas of defoliation were near timberline where moderate defoliation has been observed to do little damage.

The total area of generally moderate-to-heavy defoliation, within which some top killing of hemlock can be expected, covers approximately 620,000 gross acres. The remaining 2.1 million acres within the boundaries of the old outbreak contained black-headed budworm populations capable of only light defoliation, and this in the stands near timberline. Since heavier defoliation at timberline has been observed to cause little damage and no top killing to either western or mountain hemlock, the areas presently defoliated can be expected to make quick recovery.

Scattered light epidemic pockets of the black-headed budworm were found on Dall, Suemez, Baker and Heceta Islands west of Prince of Wales Island, and in the vicinity of Ketchikan at Ward Cove, Mud Bay and other nearby locations. The epidemic pockets on the islands were on the ocean side and were more or less widely separated from each other. No pockets are extensive in size and no serious defoliation of hemlock was observed.

Prior to 1955 it was thought that the black-headed budworm was not causing complete tree kill but only top kill, which in some stands was destroying a fair portion of tree length, especially in the largest trees. Observations made this year at Thayer Lake on Admiralty Island, and Orchard Lake on Revillagigedo Island, show that the initial assumption was not correct and that the budworm is capable of killing entire trees. Just what percent of the trees in heavily defoliated stands has been killed is yet to be determined, but initial estimates are placed at ten percent. In terms of volume the percentage of budworm kill will be higher. Furthermore, conditions have been observed which strongly suggest that hemlock, which was heavily defoliated, may continue to lose growth and eventually die. This condition was also noted at Thayer Lake and Orchard Lake and has been mentioned by other field personnel.

It must be pointed out that this hemlock kill and volume loss constitutes only a very small portion of the total timber supply, but in certain restricted areas could influence the cutting schedule.

Trend

The cold, wet summer and fall retarded black-headed budworm development to such an extent that hemlock twig sampling had to be delayed. As in previous years, trend of the outbreak is determined from budworm egg concentrations found on fixed hemlock twig samples. Defoliation can be expected to be serious when egg counts of 0.11 eggs per twig-inch of needles are reached. Results of the 1955 twig sampling are presented in table 2.

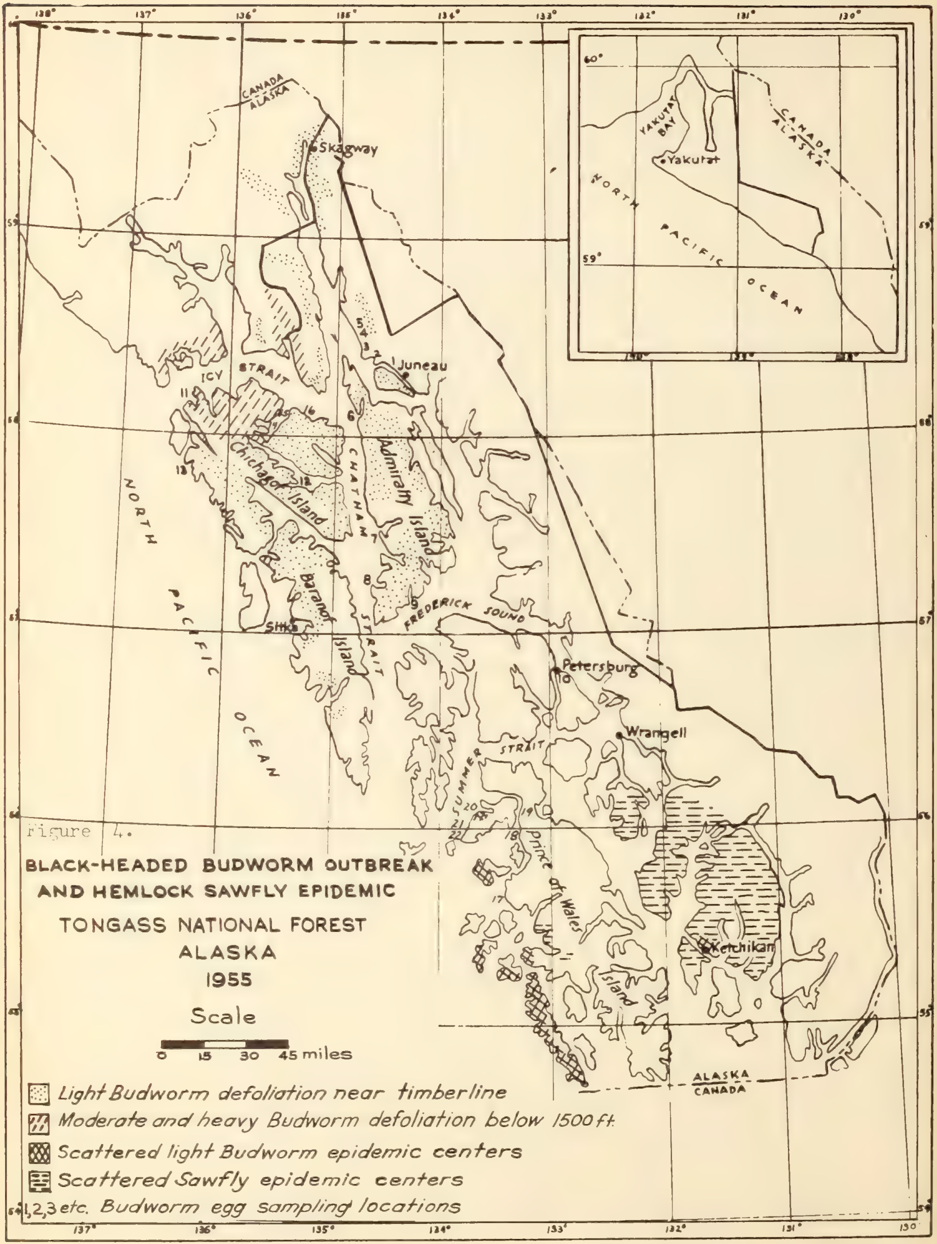


Figure 4.

BLACK-HEADED BUDWORM OUTBREAK AND HEMLOCK SAWFLY EPIDEMIC

TONGASS NATIONAL FOREST
ALASKA
1955

Examination of table 2 reveals that no budworm egg concentrations were found which can be classed as epidemic. If these samples are truly representative of actual field conditions then it is likely that the main budworm outbreak in Southeast Alaska has come to an end. It is likely that a further break-up in the area of noticeable defoliation can be expected and that some isolated pockets of defoliation may be detected within the outbreak area which will be classed as epidemic, but certainly not of outbreak proportions.

Reference to table 2 also shows that the larval parasite Elachertus glacialis Ashm. was common at a number of collecting locations. Foliage samples from which Elachertus was common showed only limited budworm damage. This parasite was so common in the Juneau area that it destroyed budworm populations which were under study.

Moths were evident at Mud Bay and Ward Cove, but evidence of parasitism, especially the larval parasite Elachertus was common. Pupal parasites were also quite evident.

The trend of budworm populations within the scattered epidemic areas at the southern end of the Tongass is not known. Ground examinations and egg counts were made on September 23 in a number of areas in the vicinity of Ketchikan. Some moths were seen but evidence of larval and pupal parasitism was common and the budworm population was low. Unfortunately, budworm development was so retarded that even at the late date of September 23 oviposition was far from completed and trend samples were inadequate.

Factors causing outbreak decline

Egg parasitism by Trichogramma minutum Riley showed no change in the Juneau area from that found in previous years. Egg parasitism was found to range from 0.8 percent to 5.4 percent.

A moderate budworm population which had been designated for parasite study was completely destroyed by parasites by the time the budworm larvae had become half grown. The chalcid Elachertus glacialis Ashm. was found in every damaged needle cluster. This parasite was also common on the foliage examined from many of the twig collecting locations.

In 1954 Microgaster peroneae Walley, Actia diffidens Cu. and Itoplectis quadricingulatus Cush. were by far the most abundant parasites of the budworm. This year Elachertus glacialis Ashm. must certainly be added to that list of parasites primarily responsible for the continuing budworm decline.

Very little evidence of disease was seen in the 1955 budworm larvae.

Table 2.--Black-headed budworm egg count data collected from hemlock twig samples. Tongass National Forest, fall of 1955.

	Location	No. of 10" twigs in sample	Twig inches of needles *	Eggs	Eggs per twig inches of needles	Date sample collected	Remarks
1.	Juneau	30	940	1	.00	October 10	Trace of sawfly
2.	Mile 14	30	940	1	.00	October 10	
3.	Mile 23	30	940	0	.00	October 10	*Elachertus glacialis* Ashm. very abundant
4.	Mile 27	30	940	0	.00	October 10	
5.	Herbert River	30	940	0	.00	October 10	
6.	Hawk Inlet	30	940	0	.00	October 10	*E. glacialis* Ashm. common
7.	Favorite Bay	30	940	1	.00	October 11	" " " common
8.	Whitewater Bay	30	940	0	.00	October 12	
9.	Eliza Harbor	31	940	0	.00	October 12	" " " common
10.	Petersburg	26	815	1	.00	October 21	
11.	Elfin Cove	29	833	11	.01	October 16	
12.	Tenakee Hot Sp.	30	940	4	.00	October 14	
13.	Chichagof Mine	30	940	0	.00	October 19	
14.	Salt Lake Bay	30	940	1	.00	November 8	
15.	Sea Gull Creek	30	940	3	.00	November 7	
16.	Spasski Creek	30	940	0	.00	November 9	
17.	Little Naukatii	30	940	0	.00	November	
18.	Sarkar Cove	30	940	0	.00	November	
19.	Sarkeen	30	940	0	.00	November	
20.	Shipley Bay	30	940	0	.00	November	
21.	French Cove	30	940	0	.00	November	
22.	Cape Pole	30	940	0	.00	November	

* Unless otherwise noted 940 inches is used as the standard sample size of 30 hemlock twigs. Unless the egg count exceeded 10, twig inches of needles were not measured.

Hemlock Sawfly

The hemlock sawfly is again epidemic, for the most part in areas unrelated to those in which the budworm is active. It is estimated that the sawfly is presently epidemic throughout 1.2 million acres in the southern portion of the Tongass National Forest. The actual area of defoliation is only a fraction of this acreage as the epidemic is in widely scattered pockets, and within pockets not all hemlock trees are being defoliated. Defoliation was first noticed by the district ranger in the George Inlet area. A subsequent ground examination revealed scattered sawfly feeding, which on some trees had removed a very high percentage of the hemlock needles. Sawfly cocoons were collected and placed in rearing for parasite emergence. To date only 5 parasites have emerged from a collection of 100 cocoons.

The areas mapped from the air in the vicinity of Craig were marked as "possible sawfly". Foliage conditions indicating very light sawfly feeding were scattered high on the slopes and were visible only at close range.

The sawfly is again active in Excursion Inlet but defoliation is less severe than in the southern epidemic area. The sawfly is not numerous enough to make combined budworm-sawfly feeding fatal to the hemlock.

Recommendations

1. An aerial survey no less extensive than the 1955 survey should be conducted in the fall of 1956. It should concentrate on the northern budworm areas and the southern budworm epidemic pockets. The outer limits of the hemlock sawfly areas should be re-determined.

2. Tree mortality plots should be established to determine the long-term effect of budworm defoliation. Plots should be established at Thayer Lake, Orchard Lake, and perhaps Frederick Point near Petersburg. These are areas of heavy top kill and some complete tree kill. Mortality cruises should also be run in these areas to determine the percent of trees killed, the volume so affected, and the rate of stand deterioration.

3. As a long-term endeavor, economical methods of determining budworm populations in terms of expected destruction must be developed. Should the tree mortality and stand deterioration studies substantiate it, perhaps the correct approach to the black-headed budworm problem in Alaska is to spray those stands of adequate volume which harbour budworm populations capable of causing extensive top kill and complete tree kill. While the outbreak of recent years has swept across millions of acres, the areas of serious top and tree kill are relatively small and expenditures to treat such areas by aerial spray might not be excessive.

4. A sawfly egg survey should be conducted in the spring of 1956 to determine the extent and severity of sawfly populations.

Effects of black-headed budworm feeding on second-growth

In order to determine the nature and amount of budworm damage to second-growth hemlock and spruce, detailed investigations were made on two areas in the vicinity of Juneau. Defoliation on these areas differed from the usual pattern in that there was no subsequent budworm feeding after the first year. While budworm damage on these areas is fairly representative of average conditions, it must be stressed that some stands of second-growth suffered much greater destruction and, of course, many young stands sustained little damage.

Budworm damage to second-growth western hemlock

In the fall of 1952, the black-headed budworm deposited an average of 2.3 eggs per normal twig-inch of foliage in the upper crowns of second-growth hemlock trees. Using this measure as a guide to the relative abundance of the budworm, larval defoliation and damage on a nearby stand of pure hemlock second-growth was measured.

The two and one-half-acre stand of hemlock second-growth originated from a clearcutting in or about 1924. Reproduction came in thick and in 1954 there were still 3220 hemlock and 100 spruce per acre in trees one inch DBH and larger. The dominant hemlock averaged 27 feet in height and 4 inches in diameter at breast height. The investigation of budworm damage, all of which occurred in 1953, was carried out on a one-tenth-acre plot within the stand of second-growth hemlock. The trees on the plot were arbitrarily set down in one of four crown classes in an attempt to show their relative size and the relation of size to budworm damage.

Damage data collected in 1954 on this plot show that budworm feeding in 1953 caused top kill in 25 percent of all hemlock stems. By crown class the percentages were: dominant - 85 percent; codominant - 52 percent; intermediate - 10 percent; overtopped - 1 percent. Length of this top kill averaged 2 feet for dominant hemlock (range 0'0" to 6'6"); 1 foot for codominant hemlock (range 0'0" to 4'8"); 1 inch for intermediate hemlock (range 0'0" to 2'2"); and .2" for overtopped hemlock (range 0'0" to 1'11").

Complete top defoliation occurred on 40 percent of all hemlock stems. By crown class the percentages were: dominant - 95 percent; codominant - 91 percent; intermediate - 31 percent; overtopped - 6 percent. Length of complete top defoliation averaged 6'8" for dominant trees (range 0'0" to 14'0"); 3'10" for codominant trees (range 0'0" to 9'0"); 1'0" for intermediate trees (range 0'0" to 8'0"); and 2" for overtopped trees (range 0'0" to 5'0").

The few Sitka spruce trees on the plot, most of which are overtopped trees, showed no evidence of budworm damage.

Graphs of radial growth since 1950 were constructed for each crown class. These graphs show a marked decrease in growth during 1953 when defoliation was in progress. An even greater radial growth reduction occurred in 1954. Growth rate continued down in 1955 but was little reduced from the previous year. Unfortunately, the budworm outbreak was so widespread in the Juneau area that no undamaged hemlock trees were available for radial growth checks. It is therefore impossible to determine how much of the loss in increment can be attributed to budworm defoliation.

Two full growing seasons after the budworm epidemic swept through the study area, all of the hemlock trees which suffered top kill still retained the dead top section. On the other hand, 84 percent of those trees had side branches that were assuming the position of leaders. Most of this new leader growth stems from single side branches at the bases of the dead sections, but a few trees have new leaders developing from bud growth. The average length of this new leader growth is just under twelve inches.

Budworm damage to second-growth Sitka spruce

The investigation of black-headed budworm damage to second-growth Sitka spruce was carried out near Juneau in a stand that was between 40 and 45 years old. The dominant spruce averaged 38 feet in height and 8.5 inches in diameter at breast height. The stand was a little more open than normal and as a consequence individual trees suffered more damage than would be found had there been more stems per acre. In sharp contrast to the well-stocked hemlock stand, the spruce area contained only 420 Sitka spruce and 40 western hemlock per acre. As in the case of hemlock, heavy defoliation occurred during only one year.

Black-headed budworm damage on Sitka spruce was generally concentrated on the current year's growth. The tops were killed in 74 percent of all spruce trees. By crown class this top kill was as follows: Dominant - 93 percent; Codominant - 86 percent; Intermediate - 71 percent; Overtopped - 29 percent. Some trees suffered top kill of both 1953 and 1952 leader growth. Half of the hemlock trees within the spruce stand also suffered top killing.

While twig killing was chiefly confined to the current growth, heavy defoliation in the tops of the spruce extended back to the 1951 needle growth in 54 percent of the trees. Heavy top defoliation throughout both 1953 and 1952 foliage occurred in 23 percent of the spruce. Twenty-one percent of the spruce suffered only partial top defoliation in the 1953 or current year's growth.

Radial growth curves made from spruce trees on the study area and from undamaged check trees show a steady decline in diameter growth since 1953 - the year of budworm defoliation. It is therefore impossible to say how much, if any, growth loss can be attributed to budworm defoliation.

Recovery of Sitka spruce second-growth is being accomplished slowly. The dead leaders have fallen from 84 percent of the trees which suffered top kill and a struggle for new leader formation is now in progress. Clusters of bud growth, as many as 12 or more buds, have formed at the tops of most of the trees which suffered top kill. Nineteen percent of the trees contain clusters of new growth in which no apparent leader, either single or double, has developed. Thirty-nine percent of the trees contained one shoot which is dominating all others, and 42 percent of the trees contain two competing shoots from the cluster. It remains to be determined if this leader competition will result in permanent tree deformity.

FOREST MANAGEMENT

Silvicultural Studies

Studies continued on the first large area clearcut for pulpwood on the Maybeso Experimental Forest at Hollis. Methods for getting good regeneration, involving basic information on seedbeds and soils, site factors affecting regeneration and the treatment of cutover areas, are still of first importance.

Residual trees

Estimates obtained by mapping indicated that a considerable number of residual trees remain on cutover areas in Maybeso Valley. Very few exist where high-lead yarding occurred, but numerous pole-sized hemlock remain on tractor yarded areas (fig. 5).

Prior to logging most of these trees were suppressed. They were slow growing, of poor form, and had sparse crowns. During felling and yarding operations they were frequently damaged and basal scars and broken tops are often observed.

In an effort to provide a guide for handling these residuals, 96 trees on a 10-acre tractor-yarded unit were selected for study. It was found that most residuals are pole-sized hemlock, formerly suppressed, but with an occasional tree as large as 16 inches in diameter. The average diameter was 9 inches. Almost a fourth had dense crowns and might become seed producers. Fifty-nine percent of the sample trees had been damaged in logging and 29 percent had other defect. Between these two forms of defect 75 percent of the trees were affected.

An annual record will include an estimate of cone crop size, mortality by cause, and evidence of decay in basal and bole scars incurred in logging. A complete retally of all the 1955 measurements and estimates, plus a replication of photographs, will be made 5 years subsequent to logging (1959). In addition, increment borings will be made to determine radial growth before and after logging, and year of any marked increase in increment due to release.

Table 3.--Type of logging damage and other defect

Logging damage	Percent of sample trees
Scars, basal and bole	54
Broken top	31
Bole splintered	1
Leaning	6
Total trees damaged	59
Other defect	
Rots, heart or butt, cat face	8
Forked, bayonet top, no leader	21
Sweep, crook	7
Other defect	2
Total trees with defect	29

Regeneration on recently logged area

A succession of four poor seed years has limited the establishment of seedlings on recently logged areas. Observations indicated, however, that numerous seedlings which became established beneath old-growth stands survived logging disturbance. A regeneration survey of the Maybeso clearcut showed that 60 percent of the area was stocked with advanced seedlings, largely hemlock, which had become established beneath old-growth stands. An additional 4 percent of the area was stocked with seedlings which became established subsequent to logging.

The advanced seedlings are well developed and appear to be in a favorable position for becoming early components of regenerating stands. The progress of these advanced seedlings will continue to be followed, however, since there is some doubt as to how many of them can survive in the open environment caused by clearcutting.

Many occur on moss-covered, undisturbed soils which are subject to high surface temperatures. These high temperatures increase seedling transpiration and deplete moisture near the soil surface.

Eight 1/4-milacre plots, on which 411 western hemlock and 55 Sitka spruce advanced seedlings existed, were established in the clearcut to observe seedling survival and growth. Four plots were on well-drained soils and four were on imperfectly drained soils. Summer mortality and growth, and winter mortality will be recorded on these plots for several years.

The study was begun in June and the first notes on mortality and growth were made at the end of September. Mortality during the first summer of record was 25 percent for seedlings less than 6 inches tall and 5 percent for seedlings greater than 6 inches tall. Considering that even the most poorly developed seedlings were tallied in June, mortality does not appear unusually high. Most of the larger seedlings are well developed and their roots penetrate into the deeper and more moist organic layers insuring adequate water despite dry soil surface conditions. These first records also indicate that mortality was slightly higher and growth less on imperfectly drained soils.

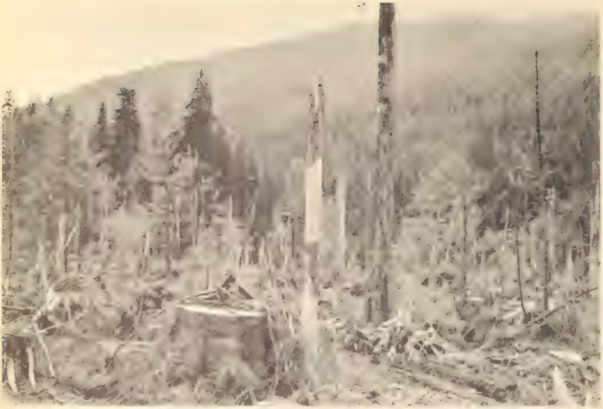


Figure 5.--Part of 10-acre residual tree study area.

Seed dispersal

The 1955 seed crop for Sitka spruce, western hemlock, and western redcedar was almost a complete failure in Southeast Alaska. This was anticipated from early season observations which indicated negligible flower and early fruit development for these species. Seed crops have either failed or have been extremely light since the bumper crop of 1951. On the basis of past records a good seed crop is overdue.

A section of the Maybeso clearcut was made intentionally large to permit determination of seed dissemination distances of the commercial tree species of this region. An area approximately one mile square has been clearcut and seed traps have been set at varying distances from the edge of uncut stands.

Other objectives of this study include:

a. Information on wind direction to determine the importance of this factor in seed dissemination.

b. Information as to when seedfall begins.

c. Abundance of seedfall by monthly periods.

d. Total seedfall per acre by distances from seed source.

A preliminary study yielding information on some of these objectives was summarized in Technical Note No. 16 issued March, 1953.

The seed crop failures in 1954 and 1955 have prevented the collection of any data for this study on the Maybeso cutting. The experiment is set up in the field, however, and with the occurrence of a good seed year results will be forthcoming.

Rodent trapping

In 1954, 30 rodent traps were set; 15 in the timber and 15 in a clearcutting to determine numbers of seed-eating rodents. Traps were set a half-chain apart and baited with peanut butter. Each trap was visited daily for three consecutive days. Six mice (Peromyscus) and no shrews (Sorex) were trapped in the woods; a value of 13.3 percent per 100 trap-days. Thirteen mice and one shrew were trapped in the clearcut; a value of 31.1 percent per 100 trap-days.

In 1955, 20 rodent traps were set only in the clearcut area and the location changed each month. Trapping was done during June, July, August, and September, and each trap was visited daily for three consecutive days.

The results of 240 trap-days in the four areas are shown in table 4. Average percent per 100 trap-days for the period June through September, inclusive, is 14.2. Of the 34 rodents caught, 16 were mice and 18 were shrews.

Seed-eating mammals and birds can limit, or completely nullify, efforts of reforestation by direct seeding. It has been found by others that a population of 6 or more mice per acre can make serious inroads into all but the greatest of natural seed falls.

Results shown in table 4 indicate a high rodent population.

All rodents are not equally bad from the standpoint of seed consumption. Deer mice feed heavily on coniferous seed. Shrews, though normally considered meat eaters, will eat some tree seed. Seed acceptance tests, plus a pilot study on rodent poisoning, will be made during the 1956 field season in cooperation with the Fish and Wildlife Service.

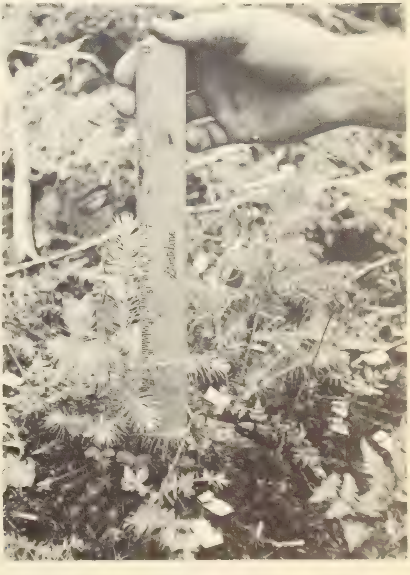


Figure 6.—Good growth of Sitka spruce on disturbed seedbed.

Table 4.--Mice and shrews per 3-day trapping period (number caught)

1955	Mice	Shrews
6/27/55	2	0
6/28/55	0	1
6/29/55	1	3
Total	3	4
Per 100 trap-days	5.0	6.7
7/27/55	0	6
7/28/55	2	3
7/29/55	0	0
Total	2	9
Per 100 trap-days	3.3	15.0
8/17/55	4	1
8/18/55	2	1
8/19/55	0	1
Total	6	3
Per 100 trap-days	10.0	5.0
9/13/55	2	0
9/14/55	1	0
9/15/55	2	2
Total	5	2
Per 100 trap-days	8.3	3.3

Relative abundance of various seedbed types

Type of seedbed is known to influence germination, survival, and growth of tree seedlings. Some seedbeds are much more favorable than others (fig. 6). Clearcutting associated with high-lead and tractor yarding creates all types of disturbance to the forest floor. In addition, fragments of the logged areas escape disturbance and the seedbed types which prevailed beneath old-growth stands remain. In order to evaluate the potential of any particular type of seedbed for establishment and growth of reproduction it is important to know its relative abundance.

An attempt was begun in 1954 to classify seedbed conditions; first by visual estimates and later by line transect samples. The results of these first attempts were given in the 1954 annual report. In 1955 the line transect sample method was modified to include the greater number of seedbed types which were being encountered. Transects were then run through the entire yarded area of the Maybeso clearcut. The seedbed types and their relative abundance are given in table 5.

A study is presently being initiated to investigate germination, survival, and growth of commercial tree seedlings on the most prominent of these seedbed types under two principal drainage conditions; restricted drainage and good drainage.

Table 5.--Relative abundance of seedbed types

Seedbed type	Percent of clearcut area
Uncompacted mineral soil	19
Disturbed organic layer	18
Undisturbed moss-covered surface	17
Moderate slash	15
Rotten wood	13
Dense slash	9
Moderate *Vaccinium* over undisturbed moss	4
Dense salmonberry and Ribes brush	2
Road and right-of-way	2
Compacted mineral soil	1
Dense herbs	less than 1
Grass or sedge sod	less than 1

Extreme temperatures in the environment of seedlings

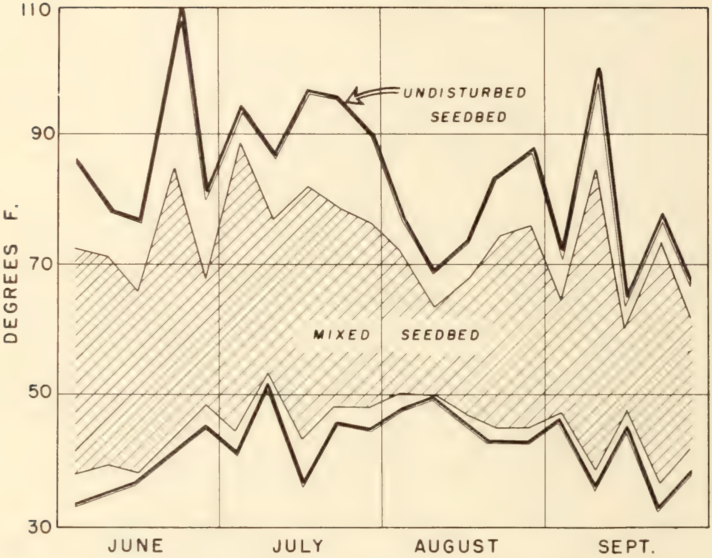
It was noted in the 1954 annual report that high surface temperatures had been observed on undisturbed, moss-covered organic layers in clearcut areas. These observations, which were of a preliminary nature, indicated that temperatures in excess of 120° F. occurred on this type of seedbed. Germination and survival of seedlings on these undisturbed seedbeds appeared poor compared to a seedbed in which the mineral and organic layers had been mixed. Poorer germination and survival were attributed to high surface temperatures which depleted available moisture.

In carrying these investigations further a record was taken of the near-surface temperature extremes and their effect on seedling germination and survival on both undisturbed and mixed-soil seedbeds. Max.-Min. thermometers were installed at 1-inch above the soil surface, at the surface, and 1-inch below the surface to permit recording of daily extreme temperatures. These two seedbed types were also seeded with equal quantities of Sitka spruce, western hemlock, and western redcedar.

The magnitude of extreme temperature differences between undisturbed and mixed seedbeds is shown by the seasonal march of 6-day means in fig. 7. Dissipation of incoming and outgoing heat in the soil is principally responsible for temperature differences between the two seedbeds; heat is more easily conducted through the tightly packed mixed soil than through the loosely packed organic soil. Maxima greater than 100° F. were frequently encountered at the surface of the undisturbed soil. The highest observed was 130° when air at 3 feet in the open reached 84°. By means of regression (analyses) it was shown that temperatures higher than 120° can be anticipated on undisturbed surfaces when air at 3 feet reaches 80°. Surface temperatures reach about 138° when air temperature is 90°. Climatological records indicate, however, that air temperature extremes higher than 85° are rarely encountered in Southeast Alaska. In contrast to the undisturbed surface, maxima higher than 100° were infrequent on the mixed seedbed.

Fig. 7 SOIL SURFACE TEMPERATURES

MAYBESO CUTOVER AREA *(6 day means)*



Minima of 32° on both moss and mineral soil surfaces result when air minima at 3 feet drop to about 36°. Freezing temperatures occurred as late as July on the undisturbed surface but never dropped below 26°.

The superiority of the mixed seedbed, when compared with the undisturbed moss-covered seedbed, is shown by these facts:

1. More seed germinated.
2. The germination period was shorter and earlier.
3. Survival of the seedlings was better.

Direct damage to seedlings because of excessive heat or freezing temperatures did not occur during the period of observation. Extreme temperatures severe enough to cause immediate damage to seedlings appear to be of little or no significance in this region.

Miscellaneous Studies

Long-log scaling tables

On the Alaska national forests, the maximum scaling length is 40 feet. Pieces from 42 to 80 feet are scaled as 2 logs; from 82 to 120 feet as 3 logs, etc. To facilitate scaling, long-log Scribner, Decimal C board-foot tables were made based on a 1-inch per 6-foot taper. They are being used for scaling Ketchikan Pulp Company logs but there has been some question as to their accuracy.

Rafts from many locations within the Ketchikan sale area were sampled, the sampling being allocated by log production of the various camps. Every tenth piece was measured using a steel tape and the volumes by the usual scale of individual logs compared with those obtained by long-log table. The ratio between the first and second method was 0.9796. The standard error of this ratio is ± .0055. The difference between the two scales is statistically significant and not due to sampling errors. This difference is caused by the fact that the sample had a taper of 1-inch per 6.9 feet whereas the long-log tables were based on 1-inch to 6 feet. From a practical viewpoint the 2.09% difference is of minor importance as a one or two percent difference in gross scale is usually acceptable in check scaling.

On the north half of the Tongass, the Assistant Supervisor made a direct comparison of the two methods by scaling 17 rafts totaling over 6 million feet. He obtained an aggregate difference of - 0.13 percent and an average difference per raft of ± 2.25 percent. It would seem that the difference in scale is negligible. An analysis of data by location of rafts indicates that the rate of taper increases from the south to the north portion of the region. Therefore the 1-inch to 6-foot taper is representative for spruce and hemlock on the Tongass. It should not be used for cedar as this species has greater taper.

Fire weather in Southeast Alaska

In our 1954 report it was shown that the moisture content of fuel sticks on the small cutover area then available fell below 15 percent several times during the summer season. These were only weekly readings. During the season of 1955, readings were taken daily at 4:30 p.m. on a 250-acre segment of the large clearcut in Maybeso Valley, a much more typical area of pulptimber cutting. The record included air temperature, relative humidity, wind velocity, 24-hour precipitation and fuel moisture content as indicated by Region 6 sticks.

During the period June 25 to September 30 fuel moisture dropped below 15 percent, the point at which litter can be ignited in the Pacific Northwest, on 37 days. The longest period it stayed below 15 percent was 7 days; the average 3.7 days during the 10 periods this happened. Fuel moisture dropped below 10 percent on 6 days during 4 periods and reached 8 percent, the lowest recorded, on 3 occasions.

Until more is known about a burning index in Southeast Alaska, we cannot say what this indicates, except that more adequate studies are needed to determine inflammability, rate of spread, etc.

Pole timber volume table

A pole timber volume table showing the gross cubic foot volumes of trees from 5.0 to 10.9 inches diameter to a 4-inch top was prepared, principally for Forest Survey use. No significant difference between the volumes of hemlock and spruce of this size was found.

Chemical brush control

Continued examination of 1954 chemical brush control tests indicate that there has been considerable resprouting of salmonberry and black currant. It view of this, and the high cost of treating brush areas in this region, it appears that other means of brush control should be explored. During logging, special measures designed to uproot or retard brush followed by direct seeding to obtain prompt regeneration of desirable tree species may offer the most feasible solution in this region to the brush problem.

Studies will be carried out in 1956 to test the results of direct seeding on potential brush areas.

Effect of Logging on Salmon Streams

It is estimated that the annual value of the fisheries resource of the Tongass and Chugach National Forests is approximately $53,000,000, representing over 50 percent of the Alaska salmon pack. The Tongass National Forest [1] in Southeast Alaska accounts for about $45,000,000 [2] based on the annual wholesale value of the pack.

The salmon fishery is not, however, the only important natural resource of this region. Dense stands of commercial timber - spruce, hemlock, and cedar - cover approximately 3 million of the 16 million acres of the Tongass National Forest with a total volume of approximately 72 billion board feet. Future development of Southeast Alaska will depend on an increasing utilization of this forest resource. It has been estimated that the forest products industry in this region will take its place with the fishing and mining activities as a steady contributor to a solid economy for the Territory.

The fisheries resource and the timber resource are intimately related. The availability of suitable spawning grounds, probably more than any other factor, controls the distribution and abundance of salmon. Concern is sometimes expressed that logging may adversely disturb the spawning facilities of the salmon streams.

1/ This study is limited to salmon streams on the Tongass National Forest.
2/ Average for period 1926 to 1953, inclusive.

The Alaska Forest Research Center,[3] began a program of research in 1949 to determine the physical effects of logging on salmon streams. The principal objective of the study is to determine whether logging by Forest Service standards[4] results in damage to the spawning facilities of salmon streams. The project is carried on as a part of the forest management program and will assess only the physical changes which occur. The biological aspects will be analyzed by trained fisheries biologists. This report presents a summary of the results of research for the first five-year period.

Four streams were selected in 1949 for long-term study. No cutting had previously been made on any of the adjacent watersheds. These streams, selected because they are representative of small- to medium-size island streams, are located in the Kasaan Bay area, Prince of Wales Island.

The study is divided into two main parts: (1) collection of quantitative information on the type and extent of physical change which takes place in these streams prior to logging, and (2) quantitative change following logging. Two watersheds will be logged; two will not be logged. It will be noted that Old Tom Creek is referred to only occasionally in this summary. This is because a satisfactory rating curve has not yet been developed for Old Tom and consequently discharge in second-feet cannot be shown.

Precipitation, soils and run-off

Precipitation is generally heavy in Southeast Alaska and is well distributed throughout the growing season. The least amount of rainfall occurs during the months of May, June and July, and ranges from 10 to 15 percent of the annual. No pronounced summer drought occurs. Streams of the Alexander Archipelago and of the mainland have typically short drainages which empty into salt water. The watersheds, which are generally small, have soils with thin, poorly developed mineral horizons, and deep unincorporated organic layers. Many muskegs, consisting of deep, poorly decomposed and waterlogged organic materials, are found in the drainage area. The prevalence of large quantities of organic matter in these soils is conducive to high water holding capacity. The impermeable nature of underlying materials, steep slopes, and general shallowness of the soils, however, severely limit groundwater storage. In addition, soils are usually near saturation in this region of high precipitation. Runoff, consequently, is generally rapid, except in streams which head in lakes, and streams are frequently reduced from maximum to minimum flow within a short period of time after rainfall stops.

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[3] Cooperating agencies include the U. S. Fish and Wildlife Service, the Fisheries Research Institute, the Water Resources Division of the U. S. Geological Survey, and the U. S. Weather Bureau.

[4] The Alaska Region of the U. S. Forest Service has long incorporated certain standard provisions in timber sale contracts and agreements for protecting salmon streams. Adequate safeguards are included in the logging plan to protect the spawning beds from damage. Protective clauses prohibit roading or yarding timber down stream beds, felling timber or leaving logging debris in stream channels, diverting streams, and others. These clauses, in most cases, are drawn up to deal with individual situations.

Most storms which occur in the study areas appear to be general in nature and deposit rain over a relatively large area. This is clearly shown by a composite discharge hydrograph for a representative period, for Maybeso Creek, Harris River, and Indian Creek (fig. 8). The watersheds of these 3 streams cover an area of about 56 square miles. It will be seen that their discharge rises and falls nearly simultaneously, in minor as well as in major variation, indicating that all three adjacent watersheds receive precipitation during all, or most, storms which are recorded at Hollis. The total amount and intensity of precipitation received, however, probably varies from watershed to watershed.

Pattern of streamflow

Rate and pattern of stream discharge strongly influences both the physical and the biotic elements of the stream. An increase in rate of discharge may have detrimental effects on the spawning facilities of the streams as water velocity is a critical factor in the movement of streambed material. When water velocity is doubled, its cutting power is increased about 4 times; its carrying power is increased about 32 times. Considerable quantities of gravel may be shifted from one position to another, carried downstream, or deposited on dry land when flood waters overflow their banks. Streambank cutting may result in the addition of considerable amounts of erosion material in the stream channel. Movement of streambed material during the period when salmon eggs are present in the stream may be detrimental to them.

Shifting gravel may destroy the eggs either by removing their protective cover, by abrasion, or by smothering due to deposition of erosion material on top of the redds. In addition, it may be physically impossible for spawning salmon to use otherwise desirable spawning beds because of high water velocity. It has been estimated that the optimum water velocity for spawning pink salmon is about 2 cubic feet per second. It has been noted in this study that in stream sections where velocity is too great, spawning is very light or entirely lacking.

The small base flow of streams is a further indication that detention storage is not great. Ground-water soon drains from the steeply sloping watersheds. The combination of steep slopes, heavy precipitation and small water-holding capacity of the watersheds results in a fairly unstable stream discharge pattern, especially in streams whose watersheds do not contain sizeable lakes. On streams without lakes, the discharge responds quickly to rainfall intensity and stream level fluctuates quite rapidly within relatively short periods of time. The flashy nature of storm runoff is shown by an analysis of a storm which deposited 1.25 inches of rain within 16 hours on the Maybeso Creek drainage. The creek rose from a height of 0.8 feet to a height of 2.6 feet within a few hours after the first rain fell on the watershed. Additional evidence of the highly fluctuating nature of streamflow is found in an examination of the ratios between high and low stream flow stages. This ratio varies between 42:1 and 152:1 in the three streams, Maybeso, Harris, and Indian. In general, stream discharge

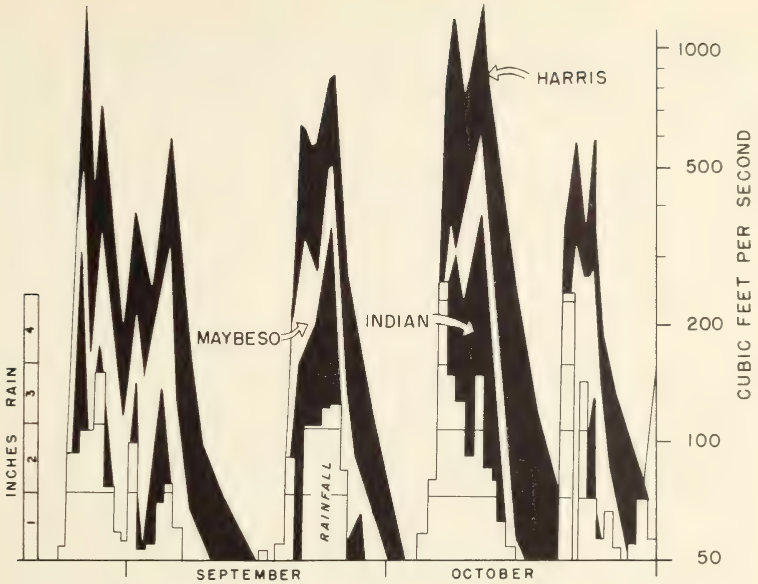

Fig. 8 DISCHARGE OF THREE STREAMS RELATED TO RAINFALL

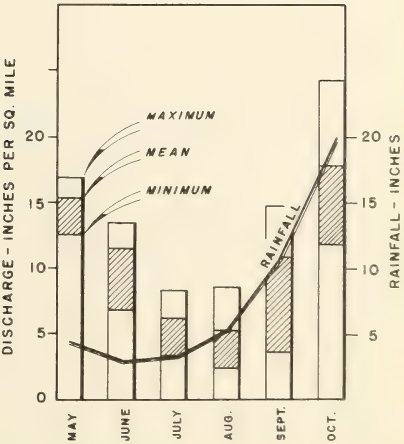

Fig. 9 MONTHLY DISCHARGE and RAINFALL 1949—1953

MAYBESO CREEK

varies between 10 and 19 cubic feet per second per square mile of watershed. A close relationship exists between precipitation intensity and stream stage. Heavy precipitation falling during the months of October, November, and early December results in many floods which produce a highly fluctuating hydrograph. Cold weather from December through April is responsible for a declining flow. The hydrograph drops in a long and flattening curve.

Snowmelt begins in May and produces a gradually rising stream-stage hydrograph which shows a diurnal peak and trough corresponding to the crest made by melted snow which is added daily to streamflow. When the snow is gone, the flow declines and the hydrograph drops in a long, flat curve on which the occasional summer storm places minor peaks. Storm frequency and intensity generally begins to increase in September. Each stream has its own individual runoff pattern which varies with the general characteristics of its drainage area.

Relationship between precipitation and runoff

Fig. 9 shows graphically the average, maximum and minimum monthly stream runoff in inches per square mile of drainage area for the period May through October. Table 6 presents a summary of mean monthly runoff and stream stage values. Maximum water loss takes place through evaporation and transpiration in Southeast Alaska from May through September. This relationship is reflected in fig. 9 which also shows monthly precipitation. During May, at the lower elevations, rainfall rates are high, temperatures increase, vegetation begins to grow, and evaporation and transpiration rates increase. Precipitation generally decreases to its lowest value beginning in June, and increases each month from July through October. Though precipitation is greater during July and August than in June, fig. 9 reveals that streamflow for these two months is considerably less than in June. These streamflow differences result primarily from two factors: (1) snowmelt contributing to streamflow beginning in April and generally reaching its peak sometime in June; and (2) loss of water through increased evapo-transpiration rates.

Evaporation and transpiration rates decrease considerably in October and stream runoff swings sharply upward. Precipitation is heavy during this month - generally the wettest month in Southeast Alaska - and quite rapidly satisfies any soil moisture deficit which might have resulted from evaporation and transpiration. Stream discharge generally continues to increase through the months of November, and a portion of December, until cold weather and snowfall result in storage of precipitation in the form of snow. Rains are quite common during this season when the watersheds may be frozen and snow-covered. Associated runoff is rapid following these rains. Runoff is also very high during spring when the soils are saturated by snowmelt. Records for the period 1949 to 1953, inclusive, show that snow first begins to melt in Maybeso Creek drainage sometime in April, or early May. The stream hydrograph record shows that snowmelt swells stream discharge until sometime in July. Referring again to fig. 9, it can readily be seen that the magnitude of stream runoff during the months of May and June is considerably out of proportion to precipitation intensities received during these months. A considerable quantity of this total runoff comes from snowmelt.

Table 6.—Mean monthly discharge and stream stage*

MAYBESO CREEK

Month		1949	1950	1951	1952	1953	Mean	Median
May	Discharge	--	12.8	15.2	17.0	16.6	15.4	15.9
	Stream stage	—	1.92	2.06	2.17	2.15	2.08	
June	Discharge	12.2	13.1	11.3	13.8	7.1	11.5	12.2
	Stream stage	1.84	0.97	1.82	2.01	1.54	1.84	
July	Discharge	6.1	7.0	5.6	8.3	3.6	6.1	6.1
	Stream stage	1.42	1.49	1.31	1.55	1.17	1.39	
August	Discharge	7.0	8.7	2.7	4.5	3.8	5.3	4.5
	Stream stage	1.43	1.48	1.05	1.20	1.14	1.26	
September	Discharge	13.2	11.5	3.8	14.4	12.1	11.0	12.1
	Stream stage	1.63	1.74	1.15	1.93	1.77	1.64	
October	Discharge	24.6	13.5	11.8	16.8	23.0	18.0	16.8
	Stream stage	2.36	1.79	1.72	2.05	2.41	2.07	

* Discharge - inches per square mile of drainage
Stream stage - feet and tenths

The analysis of data for Harris River and Indian Creek showed that their watersheds react to precipitation in the same manner as Maybeso Creek. Only minor differences exist between all three streams.

Storm analyses

Magnitude and frequency of floods are considered to be valuable aids in evaluating the effects of changes in land use on stream regimen. Serious disturbance or removal of forests may have definite effects on the magnitude of flood flows. A marked increase in magnitude of discharge, or frequency of flood peaks, following logging is a strong indication that the changes are attributable to forest cutting; providing there has been no significant change in climatic factors.

Floods were catalogued for the entire period of record. A minimum peak of 4.0 feet (water stage) was used as a basis for storm comparison. The frequency of flood peaks, according to number and periodicity, was also summarized for all streams (table 7).

The highest frequency of floods occurred in October on Maybeso Creek, Harris River, and Indian Creek. The greatest frequency of storm peaks occurred in the 4.00- to 4.99-foot class for all streams. Very few flood peaks exceeded 7 feet.

The ratio of maximum to minimum stream discharge is an indicator of the water storage function of a watershed. It is an indicator of change in hydrologic characteristics of the watershed following change in land use. The ratio of maximum to minimum streamflow has been found to be larger for disturbed or denuded areas than for undisturbed areas. As an illustration, in the Wagon Wheel Gap experiment it was found that before denudation the ratio was 12:1, and after cutting it was 17:1. This ratio varies widely between streams according to many factors.

Table 7.--Seasonal distribution of floods

	1949-1953 inclusive								
	Number of flood peaks, 4.0 feet gage height and higher (rounded to nearest whole number)								
Month	Maybeso Creek			Harris River			Indian Creek		
	5-yr. ave.	Max. 1-yr.	Min. 1-yr.	5-yr. ave.	Max. 1-yr.	Min. 1-yr.	5-yr. ave.	Max. 1-yr.	Min. 1-yr.
January	1	1	0	1	2	0	0	1	0
February	0	1	0	0	0	0	0	0	0
March	1	2	0	0	1	0	1	3	0
April	1	1	0	0	2	0	0	0	0
May	0	1	0	1	2	0	0	0	0
June	0	1	0	0	2	0	0	0	0
July	0	1	0	0	0	0	0	0	0
August	1	3	0	1	2	0	0	0	0
September	2	4	0	4	6	0	1	3	0
October	5	6	4	7	9	6	1	3	0
November	2	3	2	3	6	2	0	1	0
December	2	4	1	2	5	1	0	1	0

Ratios between maximum one-day flood and minimum one-day flow are not realistic because one abnormally high discharge rate distorts the average for the 5-year period. Median values show the following ratios:

	Maybeso Creek	Harris River	Indian Creek
Median flood, cu. ft./sec	802	1250	456
Median flow, cu. ft./sec	17	30	3
Ratio	47:1	42:1	152:1

Ground-water depletion

The principal source of water for streamflow during rainless periods is the ground-water flow resulting from infiltration of precipitation during storms. Minimal streamflow is a sensitive indicator of change in stream regimen and watershed characteristics resulting from the removal of trees from the watershed.

Ground-water depletion curves for Harris River, Maybeso Creek and Indian Creek are quite similar to one another in shape and slope as shown in fig. 10. The only major difference is in magnitude of discharge, with Harris River showing the highest values, Indian Creek the lowest, and

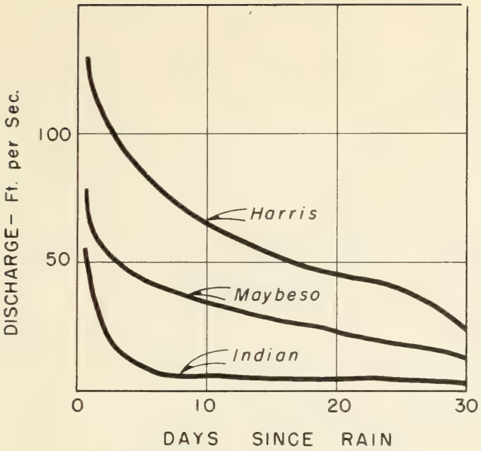

Fig. 10 GROUND WATER DEPLETION CURVES

May to Oct. incl.

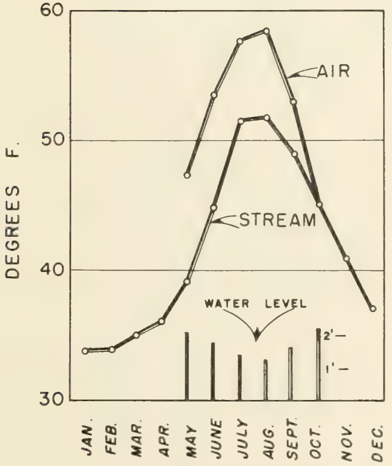

Fig. 11 MEAN MONTHLY AIR and STREAM TEMPERATURES with CORRESPONDING WATER LEVEL

MAYBESO CREEK

Maybeso Creek intermediate. The ground-water depletion curve for Maybeso Creek shows that base flow drops from approximately 35 c.f.s. after 10 rainless days to approximately 13 c.f.s. after 30 days. Base flow of Harris River ranges between about 64 c.f.s. after 10 days to approximately 26 c.f.s. in 30 days. Indian Creek base flow is the least and ranges between approximately 5 c.f.s. after 10 days to approximately 3 c.f.s. after 30 days.

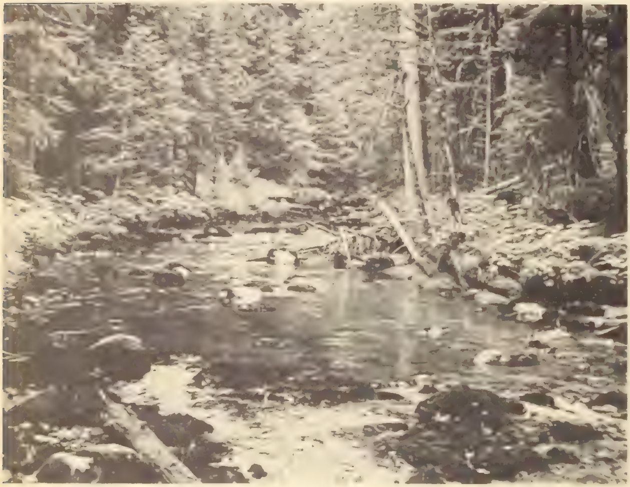

Figure 12a.—Maybeso Creek at low stage. Gage 1.02 feet. Discharge 24 second feet.

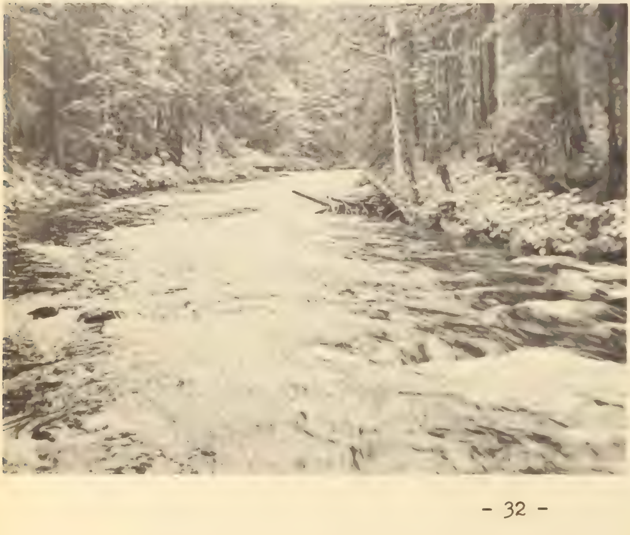

Figure 12b.—Maybeso Creek at high stage. Gage 4.0 feet. Discharge 782 second feet.

Base flow values for the three study streams discussed above are in order of magnitude of size of watershed[5]. This is a rather strong indication that base flow characteristics are, among other factors, a function of watershed size.

The effect of deforestation on the minimum flow of streams is variable. Deforestation may decrease interception and transpiration more than evaporation is increased, thus augmenting streamflow whether at flood or at minimum stages. In other cases, denudation has been found to reduce the minimal flow because of an increase in surface runoff with a resultant reduction of infiltration. Date of summer minimal flow may be later as a result of deforestation.

Continuing observations will show what effect, if any, clearcutting has on magnitude of base flow and date of occurrence of minimal flow.

Stream temperatures

Fresh water temperature plays an important role in the life cycle of salmon in the streams of Southeast Alaska. Temperature may influence the spawning impulse; it influences egg incubation, and fry development up to the point of emergence from the gravel. Stream temperature exerts its influence on various phases of the life cycle of the salmon during all months of the year. Pink and chum salmon fry do not remain in the streams during the entire year, but the fry of other species may spend one or more years in the parent stream. A study of fresh water temperatures must, therefore, evaluate conditions which occur from the time that salmon enter the stream to spawn until the fry leave the parent stream for salt water.

Maximum fresh water temperatures. Temperature of fresh water streams in Southeast Alaska is moderate. The highest mean temperature recorded for any month for any study stream was 57.4° (July, 1951, Old Tom Creek). The highest instantaneous temperature recorded during the period 1950 through 1953 on any stream was only 66°, occurring twice during the period of record. Both of these maximum temperatures occurred in July of different years. Of 71 temperatures between 61° - 66°, all occurred during the months of June, July, and August; 5 in June, 36 in July, and 30 in August. The study streams are generally devoid of pink and chum salmon during these months, with the exception of late August when a few early spawners may enter fresh water. Duration of these maximum temperatures was short, averaging 3.7 hours. Longest duration was only 6.5 hours.

Minimum fresh water temperatures. Water temperature records during late fall and winter are not as complete as are the records during spring and summer. 1953 is the only full year of record, covering all months, available from each study stream. These records do, however, permit an evaluation of minimum temperatures experienced during the winter months.

5/ Size of watershed in square miles: Harris River, 31.8; Maybeso Creek, 15.2; Indian Creek, 8.6.

The lowest mean water temperature recorded for any month for any stream was 33.4° (January 1953, Indian Creek). The lowest instantaneous temperature recorded was 30°, occurring in May. The longest duration of this temperature was 11 hours. Temperatures of 32° occurred several times during January and February, 1953, and held for as long as 6 days. Temperatures of 33° were common and persisted for periods up to 11 days. A layer of ice 6 to 12 inches thick may form in the streams during extended periods of cold weather, but the streams continue to flow under this ice layer.

Relationship between water temperature and other factors. Data from all study streams indicated a strong direct correlation between air and water temperature (fig. 11). Other investigators have also found this, and in the absence of complete water temperature records, air temperatures may be used to indicate them. Snowmelt seems to modify water temperature. A change in time and rate of snowmelt, or in total snow accumulation, may influence the fresh-water temperature regime. The stream discharge records permit an accurate determination to be made of dates of first and last snowmelt.

A strong inverse relationship seems to exist between water temperature and stream stage, as shown in fig. 11. A lowering stream stage resulted in a rise in water temperature and vice versa. Highest water temperatures were associated with the lowest stream levels; the lowest water temperatures with the highest stream stages.

During months of light precipitation - June, July, and August - stream stage continuously lowers. Shallow water responds more quickly to changes in air temperature than does deep water. Mean monthly water temperature of Indian Creek, the shallowest of the study streams, was several degrees colder during winter months, and generally warmed more quickly during the summer months than the other streams. Precipitation was found to modify maximum and minimum water temperatures during, and for a period of 24 to 48 hours following, a storm but otherwise had little effect. The variations were very small, however, and did not lower average water temperature during the storm period.

It is not expected that stream temperatures will change significantly as a result of logging. Minimum stream and streambed temperatures are probably more important considerations than are maximum temperatures in the life cycle of the salmon in Southeast Alaska. Continuing records will be kept on all study streams to obtain water temperature records during all months of the year.

Stream channel change

Continuous change in beds and channels of streams is a natural phenomena. Most of the valleys and mountains of both the mainland and the islands were buried under an ice sheet during the Pleistocene epoch. Glaciation has resulted in the formation of broad, flat-floored and U-shaped valleys with steep sides. Earthslides may block streams as a result of the weathering of certain rock formations, and the saturation of soils which allows the mass to slide from the steep slopes. Aerial photos and ground reconnaissance indicate that approximately 250 years ago a large slide blocked Harris River and changed its course.

The choking of stream channels by material other than landslides is of relatively common occurrence. High flood water undermines many trees growing along the stream channel. Stream banks are cut in one section and filled in another; new gravel bars are formed, others are washed out. Evidence of this change can be readily seen in mud-bars, cutbanks, in log tangles embedded in stagnant pools, and in many other forms. Especially vulnerable to change are unstable streams which are subjected to flash floods during periods of heavy precipitation. This change is characteristic of many of the salmon streams of Southeast Alaska, but the rate and extent of this change over relatively short periods is not known. As it is not known to what extent, if any, the process of change may be accelerated by logging, the extent of change which occurs over relatively short periods of time, both prior to and following logging, has been recorded on all streams.

Mapping of all test streams was begun in 1949. The following detail was mapped in place on a scale of 50 feet to the inch.

- a. Size and number of logjams
- b. Number of windfalls and pieces of debris
- c. Character of streambed, i.e., whether sand, gravel, bedrock, etc.
- d. Streambank cutting
- e. Pools and riffles
- f. Gravel bars and stream channels
- g. Vegetative type along streambank

Debris. The amount of debris in streams is cyclic in nature. Some years a total accumulation takes place; other years extreme floods may flush much of the debris out of the streams. The mapping project indicated that the period 1949 through 1953 has been one of accumulation. Heavy accumulation of debris in critical areas is harmful in that it may block the upstream migration of spawning salmon. Debris may change the stream course and thus set up a reaction which is felt for many miles downstream.

The effect of debris and logjams in streams is not as yet fully known, however. The presence of this material may be beneficial as well as harmful. Stream barriers are generally transient in nature and new channels are soon formed under or around these barriers.

During the mapping process and spawning surveys it was observed that salmon congregated in places where a protecting cover of debris existed. Considerable variation takes place from year to year in total amount of debris in these streams under natural conditions.

Riffles. Area of the stream in riffles does not appear to be greatly changed from year to year as a result of water action. Riffles mapped during 1949 were still present in the same general position in 1953 on all streams.

Streambank cutting. Very little cutting of overhanging mud and clay banks has occurred in any study stream during the period 1949 through 1953. Maybeso Creek has approximately 1300 lineal feet of streambank cutting; Indian Creek, 450 feet; Harris River 100 feet; and Old Tom Creek, 165 feet.

A considerably greater amount of channel change and streambank cutting occurs than is indicated by the above figures, however. The greatest proportion of streambank material is sand and gravel. The glacial-lain deposits of sand and gravel, over which the majority of these streams run their course, are easily molded and reworked. It is usually difficult to recognize, and to map planimetrically, fresh cutting in sand and gravel unless the change is of large magnitude. Several cross section stations were established on Maybeso Creek and Harris River, in 1954 and 1955, which will permit a quantitative analysis of the magnitude of cutting in sand and gravel banks. An intensive study at the confluence of Harris River and Indian Creek, begun in 1950 to measure streambed contour change as a result of deposition and bottom scour, also allows a quantitative analysis to be made of cutting in sand and gravel.

Intertidal zone change. The intertidal zones[6] of many streams in Southeast Alaska are widely used by pink salmon (Onchorhynchus gorbuscha) as spawning areas. A very high percentage of the total number of pink salmon using Harris River and Indian Creek have been observed to spawn in the riffle area at the confluence of these two streams. Salmon eggs and fry buried in the gravels in this zone are covered with salt water during a substantial part of the incubation period.

The intertidal zone at the confluence of Harris River-Indian Creek is composed of alluvial deposits of sand and gravel. Intertidal sections are frequently less stable than stream channels above high-tide level, and streambed material is easily molded and reworked by heavy fall and winter floods. The stream mapping project, mentioned earlier, showed that a considerable amount of streambed material is shifted annually in this zone.

The welfare of salmon eggs and fry which are in the streambed gravels is directly affected by the magnitude of movement of fragmental mineral debris - gravel, sand, silt, and clay - in important spawning areas. Heavy mortality of eggs and fry might occur as a result of the deposition of fine material, or streambed scouring which removes the protective covering of gravel.

Another agent of disturbance in intertidal areas is the action of winter ice. Large sheets of ice are broken and moved over the spawning beds. This action results in considerable grinding and scouring of streambeds. Quantities of rock and sediment are deposited in the grass flats when this ice is forced out of the stream channels onto the banks.

6/ The intertidal zone is considered to be the stream sections between the lower low-tide and higher high-tide level.

The importance of intertidal zones in the life cycle of the pink salmon necessitated a study begun in 1950 to measure quantitatively the movement of sediments which occur from year to year in the intertidal zone at the confluence of Harris River and Indian Creek. This zone is unstable under natural conditions and subject to considerable movement of streambed material; more so than material above high-tide level. For one thing, the intertidal section consists of deposits of alluvial material which are easily molded and reworked and which have been transported from upstream sections. Secondly, the intertidal zone may be more susceptible to sediment deposition because tidal action in this reach produces a fluctuating reservoir. Deposition is induced during periods of slack water because the incoming tide reduces the particle-carrying capacity of the fresh-water stream. Deposition of material is also induced by the chemical action of flocculation and precipitation. The greatest amount of shifting usually occurs during periods of high stream runoff, particularly during the fall months when eggs are in the gravel.

The average depth of pink salmon nests is 6 to 8 inches[7/]; it usually ranges from 4 to 12 inches. Scouring which removes material to a depth of 9.0 inches or more would wash a high percentage of the deposited eggs from their nests. The percent of streambed receiving disturbance greater than 9.0 inches was small, however, averaging only 2 percent over the period, with values ranging from 1.3 to 3.7 percent.

Percent of streambed receiving cutting disturbance in the 5.1- to 9.0-inch class is relatively high. Average yearly disturbance is almost 7 percent with values ranging from 1.6 to 12.2 percent. Scouring in this depth-class would very likely have a significant effect on egg survival. The eggs which were not washed from their nests would be covered with only a thin layer of gravel. These eggs might be more susceptible to low water temperatures than eggs which have a thicker covering of gravel.

The effect of additional material on top of pink salmon eggs which are buried at a normal depth of 6 to 8 inches is not known. Addition of a few inches of gravel probably has little effect on the buried eggs. An additional over-burden of 9 or more inches might possibly have significant consequence on both eggs and fry. This consideration is probably one of small significance, however, as an average of only 3.2 percent of the stream was affected by deposition greater than 9 inches depth.

The principal factor is the nature of the deposition material, i.e., whether gravel, sand, silt, or clay. Finer deposits such as would result from the dropping of suspended sediment loads would be particularly harmful. The "reservoir action" at the intertidal zone may cause deposition of considerable quantities of suspended sediment which might silt the spawning beds and cause heavy mortality to both eggs and fry buried in the gravels. Part of this load would probably be carried out to sea again by ebb tide currents, but part of it undoubtedly remains in place. This phase has not been investigated to date.

[7/] Hanavan, Mitchell G., and B. E. Skud. Intertidal spawning of pink salmon. Fishery Bulletin 95, Vol. 56, pp. 167-185, 1954.

The volume determination shows clearly the unstable nature of the intertidal zone in terms of cubic yards of material moved during a typical winter period. Five hundred fifty-six cubic yards of material were moved in a 200-foot section between July 1953 and July 1954. An examination of nine cross sections uniformly spaced over the study area shows that deposition which occurred in the reach between stations 0 + 00 and 2 + 00 was typical of the other cross sections also. A total net volume of approximately 4,100 cubic yards of material was probably moved over the 1375 lineal feet of stream included in the study.

The apparent high sensitivity of the Harris River-Indian Creek intertidal zone to the actions of scouring and deposition make it an excellent area in which to study this phase of the investigation. The cross sections in this area will be remeasured yearly to determine whether a significant change occurs after logging begins on the Harris River watershed.

Sedimentation

Erosion material alters the environment of fish in a number of different ways and is generally recognized as harmful to fish populations. One of the most important effects is the blanketing of salmon beds with heavy silt which causes mortality to the buried eggs by retarding the free circulation of dissolved oxygen to the salmon spawn. Other changes include (1) creation of unfavorable stream bottom conditions by the retention of organic material and other substances, (2) alteration of temperature change rates, and (3) screening out light. Silt may limit the available food supply.

Several studies have been made by Fisheries men which offer rather conclusive evidence that heavy stream siltation may cause severe mortality of salmon eggs and larvae.

Figure 13.--Discharge measurements can be made by wading when water is at normal level. Maybeso Creek.

Heavily silted streams do not stop the upstream migration of mature salmon. Salmon are observed to spawn in glacial streams which carry large quantities of suspended material. The available literature provides good evidence, however, that the most successful spawning does not occur in the heavily silted waters, but in the clear water of tributaries.

Most salmon streams carry natural silt during flood stages. This material reaches stream channels by (1) surface runoff, (2) undercutting of channel banks, (3) slow gravitational creep of mantle material, and (4) avalanches and landslides. The formation of mud flats and the presence of silt at the mouths of most creeks and rivers in Southeast Alaska attest to the magnitude of the siltation process under natural conditions.

Most logging activities on watershed slopes tend to disturb the soil and result in increased erosion. Construction of logging roads, however, is generally considered to be the principal source of stream turbidity and sedimentation. Road construction on the Maybeso Creek drainage has not resulted in excessive stream siltation because they have been located well away from the streams and have generally been constructed by borrowing and end-hauling sub-grade material; sidehill road construction and sidecasting have been held to a minimum.

Material suitable for road sub-grade and surfacing is limited in this region. Two sources of road building material are available; stream deposits, and rock outcrops. Stream deposits are largely glacial till which has been reworked by streams and contain a rather high content of silt and clay. It is generally necessary to first remove these fines before the material is used for road building purposes. Washing is done in local streams. Rock outcrops, which consist mostly of shales and greenstone, must be quarried.

Use of streambed material may damage spawning beds by causing excessive sedimentation. To date, a large portion of the road-building material used in the Maybeso Creek sale area has been obtained from a small stream (Half-Mile Creek) which empties into the tidal zone below the mouth of Maybeso Creek. Approximately 100,000 cubic yards of sub-grade and surfacing material have been removed from Half-Mile Creek. The operation has resulted in the deposition of approximately 5,000 cubic yards of silt at the mouth of this stream with material being deposited to depths as great as several feet. The sediment in this little stream is considerably higher than in the study streams as shown in table 9.

The study clearly indicates the undesirability of allowing road building material to be removed from, and washed in, tributary streams which empty directly into salmon streams. To date, no gravel removal has been allowed in streams tributary to Maybeso Creek with the exception of a few cubic yards taken by mistake and which immediately showed up in the beaver pond below the point of gravel removal. See table 9.

Silt persistence, and not solely silt quantity, however, determines the amount of damage to salmon spawn. The quantity of suspended sediment in the stream, though an index to the erosion behavior of the watershed, is not an indication of the potential damage which the stream might receive. The important consideration appears to be how much of the erosion material which enters a stream remains to silt the stream bottom, and how much of it is carried out of the stream by normal floods. The greatest damage to spawning beds occurs when silt enters a stream at times other than storm periods. At such times the water velocity is insufficient to carry the sediment in suspension. Water velocities necessary to dislodge deposited particles are far greater than the velocities required to carry the same particles in suspension. The introduction of silt into streams during non-erosion periods results in a considerable amount of bottom deposition which may reduce the total amount of stream suitable for spawning. The quiet water of deep holes, and the slower parts of streams, may allow the fine material to settle and form a layer of silt on the stream bottom.

The objective of this phase of the study is to determine the degree of stream siltation which occurs under natural conditions, and to what extent, if any, it is accelerated as a result of logging on the study watersheds.

Suspended sediment. Suspended sediment samples were collected from the study streams in 1950 and 1955; 6 samples in 1950 and 12 samples in 1955. The sediment content of samples collected in 1950 are shown in table 8 below.

Table 8.--Sediment content, 1950

Date	Stream	Gage ht.(ft.)	% silt by wt.	p.p.m.
10/7/50	Harris	4.10	0.013	132
10/9/50	Harris	Not recorded	0.015	148
10/8/50	Maybeso	2.77	0.005	48
10/11/50	Harris	4.80	0.003	34
10/11/50	Harris	4.70	0.008	78
10/7/50	Indian	2.70	0.011	101

The hygroscopic nature of the filter paper requires that the laboratory analysis be made under controlled conditions where temperature and relative humidity remain constant. The 1950 laboratory analysis was not made under controlled conditions and the suspended sediment values shown above may only be approximate. The results indicate, however, that the suspended sediment content of these samples was relatively low.

The suspended sediment content of samples collected in 1955, determined by a U. S. Geological Survey laboratory, are shown below.

The number of samples collected in the past has not been adequate. An intensified program of sediment sampling of all study streams at all water stages will be started in 1956 for analysis by the U. S. Geological Survey laboratory.

Table 9.—Sediment content, 1955

Date	Location	Gage ht.(ft.)	Sediment concentration (p.p.m.) Inorganic	Organic	total
June 28	Maybeso Creek	1.78	0	1	1
Aug. 17	" "	2.32	2	2	4
Aug. 12	Harris River	2.09	0	1	1
July 2	" "	1.83	7	2	9
June 9	" "	2.40	0	1	1
June 9	Indian Creek	1.57	0	1	1
Aug. 12	" "	1.30	0	1	1
July 2	" "	0.91	7	4	11
Sept. 19	Old Tom Creek		1	1	2
Aug. 16	Hollis Anchorage		14	3	17
May 25	Beaver pond, between Maybeso Crk. and road, Mile 3		59	14	73
June 1	Half-Mile Creek		1410	107	1520

Streambed gravel. Sixteen gravel samples were obtained from Maybeso Creek in 1955. Separation has not been made of these samples to date.

The accurate sampling of stream bottom gravel to determine its content of fine material is a difficult task. The sampling tools used to date are not entirely satisfactory. Large rocks, presence of bedrock, and swift, deep water make it difficult to obtain samples in many desired locations. A considerable amount of the fine material in the sample is lost, as it is washed out in the water trapped in the sample. Because of these undesirable features a new study (buried cans of washed gravel) was initiated during the 1955 season which it is hoped will provide some realistic values of the build-up of sediment in the upper layers of the stream bottom.

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